

**FINAL REPORT
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**NEW TECHNOLOGY CZT DETECTORS FOR HIGH-ENERGY FLARE SPECTROSCOPY:
THE ROOM TEMPERATURE SEMICONDUCTOR SPECTROMETER FOR JAWSAT**

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Final Report Phase A: The Room Temperature Semiconductor Spectrometer (RTeSS)

Introduction.

Today it is generally accepted that high-purity germanium (HPGe) detectors are the best choice for construction of high resolution solar flare spectrometers operating at energies from 30 keV up to 10 MeV. HPGe instruments typically yield spectra with very high resolution (~ 1 keV) at MeV energies. However, a major disadvantage of HPGe detectors is that they require cooling to ~ 80 K which, for spacecraft operation in near orbit, demands either stored cryogen or a mechanical cryogenic cooler. Both cooling techniques have inherent drawbacks. Stored cryogens are short-lived and often severely limit the mission lifetime. Mechanical coolers add substantial volume, mass, and power requirements and can generate microphonics problems. Solar flare spectrometers that employ HPGe detectors are therefore large and expensive instruments.

The goal of our Room Temperature Semiconductor Spectrometer (RTeSS) project is to develop a small high-energy solar flare spectrometer employing semiconductor detectors that do not require significant cooling when used as high-energy solar flare spectrometers. Specifically, the goal is to test Cadmium Zinc Telluride (CZT) detectors with coplanar grid electrodes as x-ray and gamma-ray spectrometers and to design an experiment that can be flown as a "piggy-back" payload on a satellite mission during the next solar maximum.

CZT Detectors.

CZT detectors were selected for RTeSS because they show great promise for the construction of the next generation of spacecraft borne hard x-ray and gamma-ray instruments. The high average Z and large bandgap energy of CZT makes it an attractive material for detector construction. However, until recently, the thickness of CZT detectors for spectroscopy was limited to a few millimeters. The limit was imposed by the low mobility of holes in CZT material and the resultant incomplete charge collection for high-energy photons interacting more than about a millimeter from the detector cathode. The interaction depth dependence for the charge induction efficiency produces a tail on the low energy side of the photopeak that degrades the detector energy resolution. Recently, P. M. Luke of Lawrence Berkeley Laboratory demonstrated a new method of unipolar charge sensing that reduces the tailing problem and allows one to achieve very good energy resolution at high energies from much thicker detectors. The technique employs two sets of interdigitated coplanar electron grids with slightly different bias whose difference in induced charge signal is only significant when electrons are moving in the region near the collecting electrodes. As a result, electrons dominate the induced charge

difference signal and the effects of poor hole transport are nearly eliminated. By tuning the relative gains of the two grid signals one can generate a relatively constant charge induction efficiency for interactions that occur throughout the detector volume.

We ordered a large volume (1 cm^3) CZT with co-planar grid electrodes from eV products in Saxonburg, Pennsylvania, for evaluation as a high energy spectrometer. A test jig was constructed and laboratory NIM electronics were connected for testing. A large number of measurements with radioactive sources were undertaken to characterize and calibrate the detector. We also explored the influence of grid bias potentials with the goal of optimizing the charge collection and spectral resolution. By tuning the grid potentials we were able to achieve a spectral resolution at room temperature of 4% for 662 keV from Cs^{137} . That spectral resolution, which is a factor of two better than the best scintillation spectrometers, is comparable to what we need to resolve the $\alpha - \alpha$ line complex in flare spectra.

A key issue for our instrument design is the determination of the the best mounting technique for assuring survival of the CZT crystals under launch loads. We undertook a study of possible techniques for mounting the sensors. As per our specifications, eV products fabricated four test CZT detectors for us that are mounted using hard mountings (conductive silver base-mount; epoxy side-mount) and soft mounting (conductive silicone base-mount; silicone base-mount). A special test jig which will allow shake testing was constructed and a test plan was written. The shake testing for the RTeSS sensors will be done in conjunction with CATSAT sensor testing during the next phase of the project.

Instrument Electronics.

A first order design of the analog flight electronics was completed. The flight electronics can be subdivided into three functional subsystems: 1) preamplifiers, 2) shaping amplifiers, and 3) high voltage power supplies.

Induced charge signals on the two interdigitated electrode grids of each CZT detector are measured on AC-coupled Amptex A250 charge-sensitive preamplifiers. The charge signals are differenced using a simple circuit employing two op-amps and a potentiometer which allows adjustment of the relative gain for the grid signals. The relative gain adjustment allows tuning of the net charge induction efficiency to achieve uniformity for interactions throughout the detector volume. The differenced signals are subsequently amplified and shaped by multipole Gaussian shaping amplifiers (A275) with shaping time constant selected for the optimum signal to noise ratio. The Gaussian shape provides a quick return to baseline for instrument robustness at high counting rates. Designs were developed and tested for the peak track and hold circuit which permits digitization by the analog-to-digital converter. In the current design, signal pulses are

extracted from the output of an intermediate pole amplifier in Gaussian shaping amplifiers to test against the lower level threshold. Only pulses that exceed the commandable threshold level are processed by the pulse height sampling circuit. A list of flight qualified parts for this circuit was compiled.

Thick CZT detectors require a high voltage bias in the range from -100 to -1500 Volts. A new design for a high voltage power supply that is capable of providing the voltage was developed. This student designed power-supply is a derivative of an earlier design developed in the Small Satellite Laboratory at UNH. The supply employs pulse width modulation to control an IC oscillator which drives a step-up transformer whose output feeds a three stage multiplier. Active regulation is employed through feedback to the modulation controller and filtering is used to ensure that the ripple constraints are met.

Microcomputer.

A feasibility study for the use of a COTS (commercial off-the-shelf) PC/104 card with an embedded 80386 system was completed. Part of the study, performed by two graduate engineering students, is documented on-line at <http://www.ece.unh/links/as/project.htm>. It was concluded that a ruggedized PC/104 standard card could be modified for use in the RTSS. Our current design employs a Real Time Devices CMi386SX33 cpu module with all electrolytic capacitors replaced with tantalum versions. The ICs will be shielded with tantalum foils that are epoxied to the IC packaging. In addition to the 386SX processor this system provides on-board ROM and RAM, serial and parallel I/O, a watchdog timer, real-time clock, solid-state disk support, and a data acquisition card. Power consumption for the system is approximately 5 watts.

Data Storage.

A trade-off study of mass storage devices was completed. Solid state devices such as IDE Flash Drives and PCMCIA Flash Disks were determined to be better suited to our application than a standard hard disk in a pressurized housing. The study also concluded that the FTL (Flash Translation Layer) PCMCIA cards, because of their robustness, minimal power requirements, low cost, and capacity of 2-85 MB, are well suited for our application. Thermal issues are a potential problem but it was found that minor modifications that add a high-conductivity from the device to its case can solve the problem. An industrial grade card, the Raymond Engineering Sentinel card, which is upgraded for thermal conductivity and hermeticity, and has an operating temperature range of -40 to +85C was identified. The Radiation tolerance of

these devices is still an open issue. The experience with PCMCIA cards in the shuttle program indicates that the use of something like tantalum foils may be required for shielding.

Radiation Environment Study.

The radiation environment for the proposed 650 km sun-synchronous orbit of JAWSAT was studied using the software package "Space Radiation" produced by Severn Communications Corporation. With 2mm of Al shielding provided by the spacecraft skin, we find a total dose rate within the spacecraft of about 4K rad/year at solar maximum. The addition of 2mm of Al shielding at the electronics box level was found to reduce the dose rate to about 1k rad/year.

Telemetry Format Design.

The telemetry format was designed and optimized for using S-Band capabilities. In the new format each gamma-ray that generates a pulse height above the LLD will be recorded as a single event. The stored event data will be organized into 16 second long major frames which carry 32 bit synchronization and 32 bit absolute UT time markers. Each event in the frame requires two 8 bit words composed of 5 bits for 0.5 second time resolution, 2 bits for detector identification, 8 bits for the event amplitude and 1 bit for parity.

Mechanical Housing.

Design of a hermetic electronic housing was completed. The housing will employ a seated gasket and a pinch tube. For flight the housing will be filled with 100 mb of dry nitrogen and sealed. A 10% admixture of helium will be included in the fill gas to allow use of a sniffer to test the hermeticity of the container. A re-design of the sensor housing was begun due to concerns about CZT crystal cleaving during launch. A study of the optimal detector mounting technique is currently underway.